The Well:

An example of a wheel turning an axle.

OBJECTIVES

Students will:

1. Understand the scientific concept of work and the idea that simple machines can make work easier.
2. Demonstrate the characteristics of a wheel and axle.
3. Investigate how a wheel turning an axle makes work easier.
4. Explore how varying the size of the wheel will affect the amount of effort needed to do a job.

MATERIALS

Each group of 2 students will need:

- 1 K'NEX Wheels & Axles and Inclined Planes Building Set with building instructions booklet
- Marker
- Paper cup
- Pennies or small paper clips
- Yardstick (Meterstick)
- Student Journals
- 200 gram or 5 Newton spring scale (optional)

You will need:

Pictures and examples of different kinds of wheels and axles. (Suggestions: plastic thread spool with a pencil inserted into its center hole; doorknob; screwdriver.)

PROCEDURE

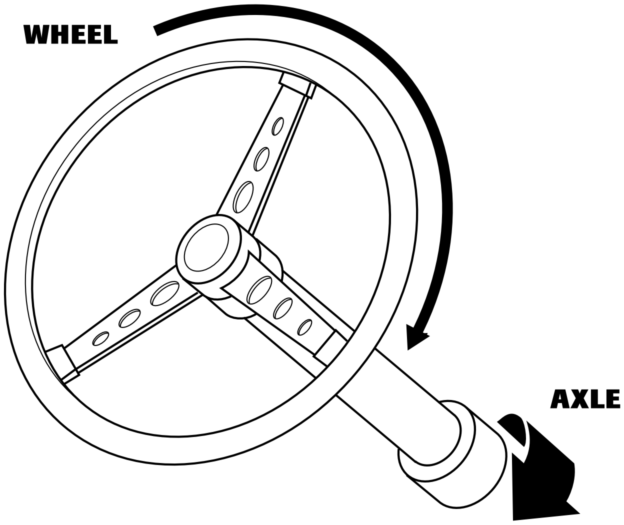
Introduction

- If this is their first introduction to simple machines you may want to demonstrate the concept of **work** by having 3 or 4 students pushing as hard as they can against a wall in the classroom for 1 minute. Then ask another group of 3 or 4 students to each push a book across his or her desk. Ask the rest of the class to decide who was doing 'work.'

- Following this, provide the students with background information on the concepts of work, force, effort, resistance, and load (See Key Terms and Key Concepts on Page 3 of this Guide.) Ask them to then identify where the effort force came from and what represented the load or resistance for both activities.

- Ask them if the wall or the books moved. Explain that although the group pushing against the wall exerted a great deal of energy or force, the wall itself didn't move so, from a scientific point of view, no work was done. The group pushing the books, however, did do work. Students should record their observations in their journals.

- Begin the lesson by defining a wheel and axle. (A definition is provided on Page 3 of this Guide.) Refer to the fact that a wheel and axle is a simple machine. Have an example available, constructed from a thread spool and pencil, to demonstrate the parts. Draw a labeled diagram on the board (See diagram below.)

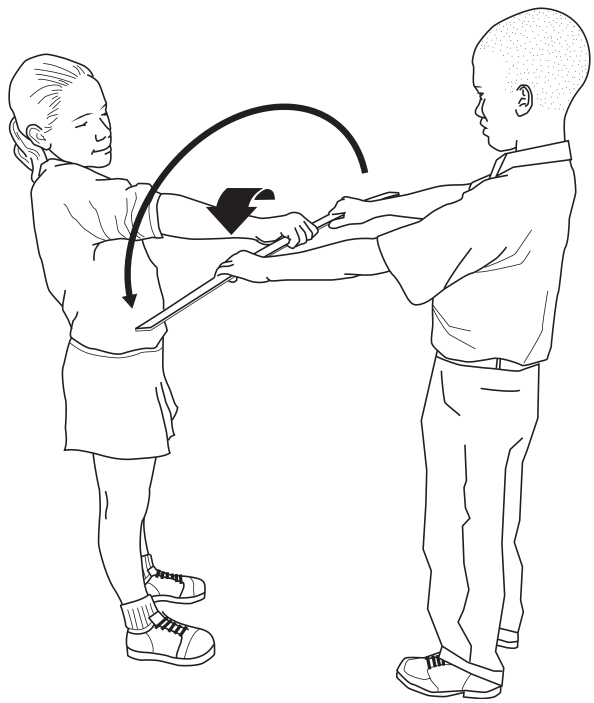


- Ask the students to provide examples of the use of wheels and axles in their daily lives. They will probably describe the wheels and axles on a car or bus. This will give you the opportunity to explain how these differ from other wheel and axle simple machines, in that the wheel moves independently from the axle and the function of the wheel, in this case, is simply to reduce friction. Probe for the less obvious examples, such as faucets, doorknobs and screwdrivers.
- Ask the group to think of ways in which our lives would be different without the use of this simple machine. Encourage them to consider the ways in which wheels and axles make our work easier every day. Ask them to suggest alternatives to doorknobs and screwdrivers. Suggest that they explore these options at home.
- Suggest that they search the Internet for additional information about wheels and axles. (Recommend that they enter the key words: Simple Machines into a search engine such as Google.)
- Organize the class into teams of 2 (maximum 3) students and distribute yardsticks.

Inquiry Activity

We would like to thank Susan Frazier and the directors of the SMILE program at the Illinois Institute of Technology for granting us their permission to include the following activity. ©1990. [Please visit http://www.iit.edu/~smile/ph9005.html for further information.]

- Explain that each team will first explore the characteristics of a wheel and axle by simulating one using their arms and a yardstick.
- Ask one member of each team (A) to grasp the yardstick in the middle and hold it out in front of them. Student B then places a hand on either side of Student A's hand and tries to turn the stick while Student A attempts to prevent it turning. Student B should repeatedly move his/her hands further apart until the stick turns easily. *(See diagram on next page.)*
- Ask the students what they think Student A's hand represented *(axle)* and what the yardstick represented *(wheel.)*
- Ask them to record the experiment in their journals together with a labeled diagram.



Building Activity

- Distribute a K'NEX Wheels & Axles and Inclined Planes building set to each group. Ask them to open up the materials and locate the building instructions booklet. If the class has not used K'NEX building materials before, draw their attention to the building tips page. It is crucial that the students grasp the building concept at this stage so that frustrations are avoided later.
- Provide some basic guidelines for maintaining all the pieces in the set for future use.
- Remind them that they will need about 5 minutes at the end of the class period for cleaning up the materials.
- Explain that they will build a model of a well that incorporates a wheel and axle system. They will then use the model to investigate how a wheel and axle can help them do work.
- Invite the students to build the **WELL** model (Pages 2-3 of the building instructions booklet.) We recommend that one student build Steps 1-3 and the other, Steps 4-7. The parts should then be assembled, as shown, to form the completed well.

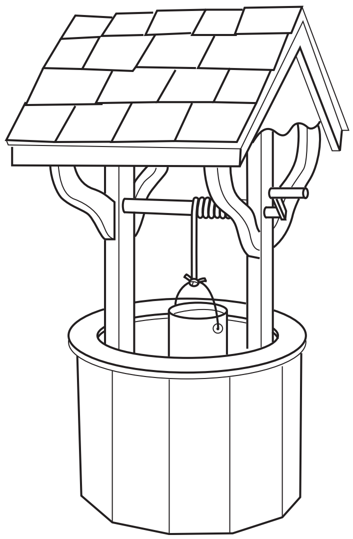
Inquiry Activity: How does the wheel and axle help you do work?

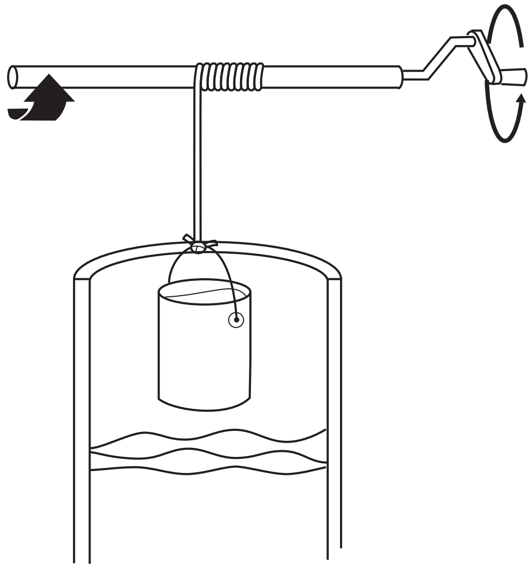
Provide each group with a paper cup filled with pennies or paper clips and ask them to feel its weight and then place the cup into the bucket of the well model. Use the following script to help the students explore the function of the wheel and axle.

Steps

1. Move two desks close enough together so that you can place one side of the well's base on one desk edge and the other side on a second desk edge. Put a book on each side to hold the model firmly in place. Lower the bucket to the floor. (See Page 3 of the building instructions booklet.)

- Ask the class to investigate the well by first locating the wheel and axle in the machine. *(The rod across the top is the axle. The crank, which turns in a circle, is the wheel.)*



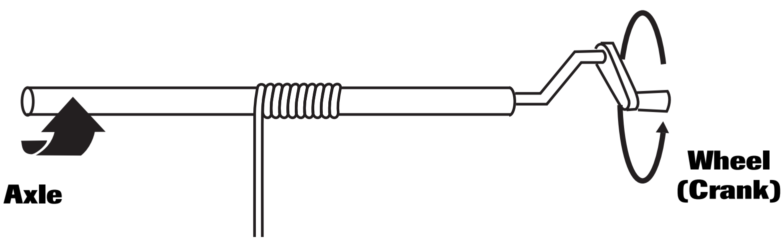


- The students should record in their journals the difference in the sizes of circumference of the wheel and axle. They should note which travels the further with one rotation. *(The wheel.)*

- Ask the following questions:

(a) Do you turn the wheel to make the axle go round? If so, the machine helps you complete the task by multiplying the force you apply.

The large wheel turns through a long distance with a small amount of effort force, while the small axle turns through a small distance, but with greater force.



(b) Or, do you turn the axle to make the wheel go round? If so, your machine helps you cover more distance at a faster speed.

The small axle turns through a small distance using a large amount of effort, while the large wheel rotates through a large distance with a small amount of effort.

Students should discover that they turn the wheel to make the axle rotate.

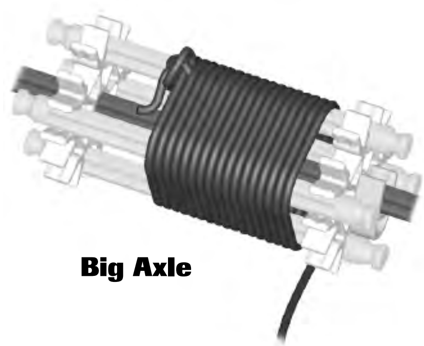
(c) Ask the students to determine exactly how the well works.

When you provide effort by turning the crank, the rod turns, winding up a rope to raise the bucket, which is the resistance or load. This simple machine makes lifting the bucket much easier than just hauling on the rope by hand.

2. (a) Start with the blue rod facing up and turn the wheel all the way around to lift the bucket. Be careful not to let go of the rod as you turn, or the string will quickly unwind and the bucket will drop.
   (b) Count the number turns it takes to raise the bucket from the floor to the top of the desk. Each time the blue rod faces up it has completed one turn. Record this number.
   (c) How far does the bucket move each time you turn the wheel (crank)?
   (d) How could a wheel and axle in a real well make it easier for you to lift a filled bucket?

Depending on the height of their desks, it should take about 5-7 turns of the crank to lift the bucket to the desktop. For each full rotation of the wheel, the bucket moves the same distance as the circumference of the axle. Students should realize that it would be easier to turn the wheel of a real well than it would be to haul the bucket up on a rope.

3. (a) Remove the yellow rods from the axle and attach the string to the red rod that now forms the axle. (See Small Axle picture on Page 3 of the building instructions booklet.)



Big Axle

Small Axle

   (b) Lower the bucket to the floor again.
   (c) Count the number of turns it takes to raise the bucket from the floor to the top of the desk. Record this number.
   (d) What do you notice as you turn the wheel to lift the bucket?
   (e) Compare the number of turns to raise the bucket for the two axles?
   (f) Which axle was easier to turn?
   (g) Why?

Again, depending on the desk height, it should take about 20-22 rotations to raise the bucket to the desktop. Students should notice that it takes many more turns to lift the bucket using the small axle than the big axle. Students will find that the small axle made it easier to lift the bucket because they had to apply less effort to turn the wheel with the small axle than with the big axle. However, they have to turn the wheel more times. Using a wheel to turn a small axle is easier than using the same size wheel to turn a larger axle.

Class Idea

Set up the building activity so that one half of the class makes the model with the yellow rods for the axle and the other half makes it with the single red rod. Then ask the students to move from one model to the other to discover which type of axle requires the most effort to raise the bucket.

4. (a) Change the size of the wheel by using longer and shorter rods and then repeat the experiment.
   (b) How do the other rods compare with the blue rod?
   (c) Do they make it easier or harder to lift the bucket?
   (d) What does this tell you about how the size of the wheel affects your work?

Students should notice that using longer rods for the wheel will make it easier to turn the axle. Shorter rods will make it harder to turn the axle. If your class has already explored levers you can explain that a wheel and axle works as a lever that rotates and tie in their knowledge about how the length of the lever arm affects the work carried out.

Applying The Idea

- Ask the students to write about the advantages and disadvantages of both axles and the different size wheels in their journals.

The small axle is easier to turn but it requires more turns to lift an object. The big axle takes fewer turns but it needs more effort to turn it. The bigger the wheel, the easier it is to turn the axle but you have to turn it through a greater distance.

- Encourage them to discuss situations where the different sizes would be appropriate.

You may use a small axle in a situation where you need to lift something heavy and you want the wheel to turn easily. You may use a big axle if you want to lift something quickly that is not very heavy.

- Ask the students to decide which combination of wheel and axle will make it easiest to lift the bucket.

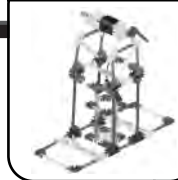
The largest wheel and the smallest axle.

- Ask the students to build and test other sizes of wheels and axles to validate their findings.

Extending The Idea

1. (a) Use a spring scale to measure the effort force you applied to lift the cup in the different situations in the activity. Attach the scale to the cup to measure the effort force required to lift it without the well's wheel and axle mechanism.
   (b) Snap a gray connector to the end of the blue rod that forms the crank (handle) of the well. Hook the spring scale onto the gray connector. Pull the spring scale straight up to lift the handle in each of the different situations in the activity.
   (c) Record and compare readings. Use them to determine which wheel and axle system requires the least, and which requires the most, effort. Explain your answers.
   (d) Calculate the work done by this simple machine. This can be calculated using the following formula:

Output Work = Weight of the bucket x Distance it moves.



2. Ask the students to calculate the Mechanical Advantage of the wheel and axle combinations they have built. Use the following directions:

   (a) Measure the diameter of the wheel or the axle – whichever one provided the **effort.** Then divide the diameter in half to get the effort radius (**ER**).

   (b) Measure the diameter of the wheel or axle – whichever one isn't providing the effort. Then divide this diameter in half to get the resistance radius (**RR**).

   (c) Divide the ER by the RR to find the Mechanical Advantage (**MA**).

   ER ÷ RR = MA

In the example of the well, where the wheel turns the axle, the MA = Radius of Wheel ÷ Radius of Axle. The calculation will result in a Mechanical Advantage of more than 1, indicating that the simple machine makes work easier by multiplying the force.

JOURNAL CHECK:

At each stage, ask the students to keep individual journals to record their findings. The following experiments, measurements and labeled diagrams should be recorded:

- ✔ Identification of wheel and axle (including a diagram).
- ✔ Description of how the well works.
- ✔ Number of turns to raise the bucket using various sizes of axles.
- ✔ Effort force required to raise the bucket using various sizes of axles and wheels.
- ✔ A table, such as the one shown below, to summarize their finding:

Small axle	Large axle	Small wheel	Large wheel
More turns to lift bucket	Fewer turns to lift bucket	Travels small distance	Travels longer distance
Less effort to turn	More effort to turn	Harder to turn axle	Easier to turn axle